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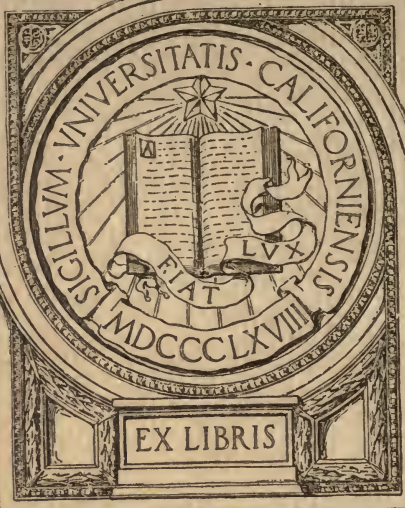

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SUGGESTIONS FOR A COURSE

IN

CLIMATOLOGY

IN CORRELATION WITH GEOGRAPHY.

BY

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WITH PREFACE BY

DR. W. N. SHAW, F.R.S.,

Director of Meteorological Office.

To be obtained from the Registrar's Office, U.C.W., Aberystwyth.
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UNIV. OF
CALIFORNIA

Suggestions for a Course in Climatology in Correlation with Geography.

BY

WALLACE E. WHITEHOUSE, L.C.P., F.R.Met.Soc.,

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PREFACE.

BY THE DIRECTOR OF THE METEOROLOGICAL OFFICE.

When I was a school-boy, five and forty years ago, one of my delights was an atlas of Physical Geography. It showed contours of land, depths of sea, ocean currents, prevailing winds, isotherms, rainfall for certain regions, the distribution of plants, animals, races of man, and many other interesting matters.

Mr. Whitehouse's little book of suggestions for a school course in Climatology reminds me of those bygone days, and I think how much original information upon the subjects has been collected and compiled in the last forty-five years. Responsible now for the production of many maps of climatological data, and cognisant of every stage in the process from the observer's instruments to the lithographer's stone, I sometimes ponder over the information which the editors of my physical atlas had to go upon when they made their maps. We had

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no thought in those days of questioning the accuracy or sufficiency of the data, or of the inferences drawn from them. A map is a map when it is finished; and, whether right or wrong, it tells a fine story. The right is often more intricate and more perplexing than the wrong, but, after all, it is better, and the scholars for whom Mr. Whitehouse suggests this course will be more fortunate than I. They are invited to consider in a practical way all the facts that go to the making of a climatological map; to observe the elements, the variations of which make our weather, and to understand how they are compiled and ultimately converted into the finished map.

It is gratifying to me that Mr. Whitehouse uses, to so large an extent, the publications of the Meteorological Office in his course. Those publications are primarily the embodiment of the public memory of the weather over the British Isles and over the oceans. Their purpose is to keep effectively on record what has been, for the use of those who want to know. But though their primary intention is not educational, they have great educational value, apart altogether from the special interest of the subjects; for education is really training in the use of past experience, and in this study one may see how fact after fact drops into its place, and how all the features that memory most requires come to be represented in a finished map that embodies a myriad of recollections. The observation and practical arrangement of the facts of weather for any locality for the purposes of organised memory are not only an educational training, but a useful store of knowledge.

Mr. Whitehouse is very liberal in his interpretation of the scope of the science of Climatology, and regards it as more effectively described as "Weather Study." There is a subtle distinction between climate and weather that is not easily defined. Climate takes account of many days of weather. Climate is, indeed, the combination and expression of all the specimens of weather that a locality produces, and the study of weather is a necessary introduction to the study of climate.

My best wishes for the success of the book are part of a desire which I have long felt to break through a certain paralysing tra-

dition that meteorological information is something for which, at the Meteorological Office, they find a mysterious use in forecasting. No one who has not tried has any idea how deceptive an unaided memory about the weather can be, and few realise how useful meteorological facts can be if you are sure of getting them when you ask for them. Practice in using them means being able to turn to practical use not only those which you collect yourself, but also the results of others' experience as well; so that for their practical as well as their educational utility Mr. Whitehouse's suggestions deserve every encouragement.

W. N. SHAW.

Meteorological Office,
August 3, 1914.

INTRODUCTION.

It is unnecessary in this place to stress the effects of climate on the plant and the animal world and on scenery.

Geographical instruction has to be correlated with Climatology so frequently, that it is unfortunate that few schools throughout Britain do really serious work in the latter subject.

This is not an attempt to force a new subject into the present well-filled school time-table, but rather a series of suggestions by which a vital section of geography can be more systematically treated.

In many schools daily observations are taken of certain climatic factors, but too frequently these observations degenerate into a careless reading of a few badly exposed, unsatisfactory instruments; the resulting data are occasionally entered up on more or less suitable forms, but little appears to be done to render the various records sources of direct and comparative information.

This short scheme is intended to be more directly applicable to Welsh schools, where the recent development in the scientific treatment of geography has been so well marked.

Climatology, or to use a less technical term, "weather study," is of peculiar value to those many communities in Wales engaged in agricultural pursuits, and yet there is, unfortunately, a dearth of data concerning climate throughout the principality. In a few districts a sufficiency of rainfall observations are made in connection with various "water-works" schemes, etc., but more frequently it is found that large areas exist in which no *systematic* readings of any kind are taken.

School children soon become efficient observers, and are quite capable of looking after a school "station"; they appreciate the trust implied, and the consequent training in accuracy will repay the time spent in supervising observational work.

Observational Climatology.

Instruments.

The instruments required will vary according to the funds available and the extent to which observational study will be continued, hence it has been thought advisable to mention here only the essential requirements of a small station. These are :—

Dry Bulb Thermometer,
Wet Bulb Thermometer,
Minimum Thermometer,
Maximum Thermometer,
Rain Gauge.

The above should be of a thoroughly satisfactory "standard" type, and for certain purposes the thermometers should be accompanied by "Kew" certificates. The rain gauge rim and measure should also have been tested.

The thermometer must be exposed in a screen of special construction, and the one in general use is the "Stevenson" type with double-louvred sides.

It is always advisable where possible to add a barometer to the list. This, if an accurate one—and all others are practically valueless—is generally an expensive item. The instrument should be capable of being adjusted for changes of cistern level, as, say in the Fortin's pattern ; or have some form of self-adjustment, as in the Kew type.

For all the instruments the initial expense should practically be the only one, as reasonable care will ensure a long life for them.

Exposure of Instruments.

In order that the observations at different stations may be comparable, the exposure must fulfil certain requirements. The perfect site is upon level ground with unrestricted exposure in all directions. This is not generally practicable, and for working purposes it may be represented by a rectangular piece of level short grass, about 30 feet by 20 feet, surrounding the screen and rain gauge, which should be not less than 10 feet apart, the screen being placed to the north of the gauge. The distance of the instruments from any object (building or tree, etc.) should be twice the height of the object.

The instruments and exposure described above would be accepted by the Meteorological Office as fulfilling the requirements for an auxiliary climatological station.

The methods of taking the daily observations (at 9 a.m. generally), and the setting and care of the instruments, and details relating to observation of special phenomena, will be found described in full in the various Observers' Handbooks. (See Bibliography.)

Arrangement of Data.

If the observations of the station be accepted by the Meteorological Office (and much is to be gained by such recognition), a supply of blank forms will be sent, on which the daily readings are to be entered; but apart from this, it is advisable to keep neatly arranged particulars of the various readings in some permanent register. Such registers are on sale by various firms which cater for geographical requirements. Additional blanks (at a nominal cost) can be obtained from the Met. Office, and a year's monthly forms could be bound cheaply for future use. Interest in the observation work can be stimulated by posting up the daily readings on some prominent school notice board.

Daily Form as used at Welshpool County School for some years, with but slight amendments, is shown below :—

METEOROLOGICAL OFFICE—AUXILIARY CLIMATOLOGICAL STATION.

WELSHPOOL COUNTY SCHOOL—262′ above S.L.

Situation :—52° 39′ 20″ N. Lat., 3° 8′ 28″ W. Long.

Readings taken at 9 a.m. on ——————————————————

State of Weather at time of observation :—

Barometer = ″. Attached Thermometer = °. Corrected Baro. = ″

Cloud: Amount: Kind: *Wind:* Direction: Force:

THERMOMETERS—Screened. ° F.				Humid.	Rain—Prev'us day.	Rain for Month.	Rainy days for Month.	Rain since Dec. 31.	Rainy days since Dec. 31.	Condition of Barom. —24hrs.
Dry.	Wet.	Max.	Min.	%	Inches	Inches	Days	Inches	Days	

Weather—Previous Day	
Special Remarks on Readings	

W. E. W.

The statistics thus collected will be used as :—

(*a*) Concrete statements in discussions relative to climate ;

(*b*) A means of teaching quantitative values of the climatic factors : e.g., young pupils have a difficulty in realising 1 inch or 1 m.m. of rain in the abstract, but after continued reference to the school statistics and their related experiences the conception becomes exact and definite ;

(*c*) Quantitative and qualitative bases for comparisons with the available published data for other regions.

Publication of School Data.

The local press in many cases is willing to collect and publish summaries of local climate. This increases the circle of activity, and at the same time provides a valuable check as to the general accuracy of any particular set of figures. An occasional letter in the newspaper will remind many open-air workers that accounts of remarkable storms, floods, or other phenomena will appeal to a considerable circle. It is possible for the school itself to act as a collecting centre for local statistics sent by gardeners, private individuals, etc. This does not mean a serious demand on the time of an interested teacher, and in any case he is well repaid by the growth of interest on the part of his pupils. In many districts private observers have only to be assured that their readings are of value to ensure a constant supply of other records for comparison with those of the school itself. Of course, rainfall returns are the most that will be sent in many cases, but these are of the greater value in any particular area, inasmuch as the rainfall distribution is usually more complex than the distribution of other climatic factors.

If the Meteorological Office be satisfied with the arrangements made by the school for observational work, and accept the observations from the "station," then the school becomes entitled to a copy of the publication in which the record appears, and, more than this, it is supplied by the Meteorological Office with the note-book and all the requisite blanks used in registering the statistics.

A copy of the Handbook, of various humidity tables, and, if necessary, a barometer correction card, are generally supplied also.

The station becomes subject to an occasional helpful inspection by one of the Meteorological Office officials, which in the case of volunteer observers is rather to be encouraged than deprecated.

The Rainfall returns, either monthly or annually, are welcomed by the British Rainfall Organisation (B.R.O.), and here again the requisite blanks are supplied gratis. The B.R.O., which is not a government institution, issues authoritative publications of the greatest value to teachers. By making application, observers are usually supplied with a free copy of the general table of rainfall for the year of their record; and by application in advance they can obtain a copy of the annual "British Rainfall" for 5/-. This is half the published price, and is below the actual cost of production of a volume which contains an immense number of interesting and carefully scrutinised data.

Data for Comparison.

It will be advisable to obtain some or all of the literature referred to later, so that the local record can be compared with others. At the same time many of the suggested exercises appended will demand the use of such publications. Additional sources of supply for extended problems in climatology are mentioned in the Bibliography *(q.v.)*

Publications of the Meteorological Office.

Those of greatest value for ordinary school purposes are:—

(*a*) The Daily Weather Report (D.W.R.).
(*b*) The Weekly Weather Report (W.W.R.).
(*c*) The Monthly Weather Report (M.W.R.).
(*d*) Monthly Charts of the Oceans (M.C.).—Atlantic (M.C. 1); Indian (M.C. 2).

A short description of each of these periodicals is given, as although some of them are in regular use, yet they are still insufficiently known in many schools.

Daily Weather Report.

This is a four-page lithographed sheet, on issue daily (Sundays excepted) at the Meteorological Office after 1 p.m. Price one penny per copy. The D.W.R. may be obtained on payment in advance at the Met. Office of the cost of transmissions (postage and wrappers). The subscription for this service is at the rate of £1 per annum, minimum 5/- for a quarter ending March 31st, June 30th, etc. Individual months are at the rate of 2/- per month. Two copies per day in the same envelope will be sent at the rate of 7/- per quarter or 27/- per annum. For educational purposes, on the receipt of sufficient notice, additional copies will be printed off at the rate of 10 for 7d. (postage extra), for any day or succession of days. It is also pos-

sible to obtain a supply of D.W.Rs. with pages 1 and 4 printed on separate paper from pages 2 and 3. Such copies are sold at 10 for 1/2. Surplus copies of the D.W.R. are occasionally available for educational purposes, upon application to the Director. No charge is made for this service, but postage must be defrayed.

Page 1 of the publication contains the data received by telegraph from, at present, 31 British stations, 37 Continental stations, and 8 stations in the islands of Spitzbergen, Iceland, Faröes, Azores, and Madeira. The information which is received at the Office in code form is tabulated, with an explanation of all abbreviations. For British stations the Report generally gives barometer, temperature, wind and weather, at 7 a.m. of day of issue and 6 p.m. of the previous evening. The readings for the later hour also include information relating to barometric and temperature changes, upper cloud movement, and state of sea. A third table gives rainfall, maximum and minimum temperature, weather and sunshine, of the previous 24 hours. For the remaining stations, the third table is less complete, weather and sunshine not being given.

Page 4 contains additional readings from some 54 British stations (chiefly seaside pleasure resorts). Brief notes on the previous day's weather are given, and an interesting table at the top of the page contains observations, from the Atlantic Ocean, received by radio-telegraphy.

Page 2 indicates by means of suitable maps the barometric pressure, winds and weather, at 7 a.m. and 6 p.m. of the previous day. The sea area is marked in blue tint, and isobars are shown by bold black lines. The district forecasts, with map of districts and announcement of storm warnings, occupy the remainder of the page.

Page 3 is practically filled by a synoptic chart showing the general situation at 7 a.m. with isobars in full lines and isotherms marked by dotted lines. The normal temperature of the sea is shown by blue tints of varying intensity. Since May 1st, 1914, the description of the synoptic chart which completed the page has been omitted, but the chart has been extended northward to include the whole of Scandinavia and Spitzbergen. An inset map of the British Isles on the same scale has been added, to show further information relating to temperature, weather, and sea disturbance. The Sunday chart, issued on the following Tuesday, contains particulars relating to pilot balloon ascents for the past week, in lieu of the usual forecasts.

Weekly Weather Report.

This is less frequently used for general teaching purposes. Still the plotting of the weekly results, normal and actual, gives the best conspectus of the sequence of weather through the year. The problem to which the W.W.R. addresses itself is the presentation of a general result for a *district*. For many agricultural and health problems, the month is too long and the single station not sufficiently representative. Actual application of statistics from these standpoints requires the *difference from average* or *normal*, hence the particular value of the W.W.R.

It is a four-page folder containing a four-page inset of maps, and is published on the Thursday of each week, price sixpence. The first half of page 1 consists of "General Remarks" on the meteorological conditions of the British Isles for the week ending on the Saturday preceding the day of issue. Weather, temperature, mean temperatures of the sea, rainfall, sunshine, pressure, and wind are discussed. Then follow analyses of the weeks' warmth, rainfall, and sunshine, in comparison with the average for that particular time of year. Similarly the season to date is analysed, and the analyses of the four past seasons are given for reference. [Incidentally the seasons are dated rather differently from the usual arrangement of the ordinary calendar: spring, for example, begins on the Sunday nearest the first of March; summer on the Sunday nearest the first of June, and so on.]

Pages 2 and 3 contain the statement of many climatic factors, including "Accumulated Heat" for the week in "Day degrees," Ground Frosts, etc., in addition to the ordinary data. About 120 stations in the British Isles return records, not all of which, however, contain a complete set of readings. Page 3 also contains a small table giving certain sea temperature records.

Page 4 states a useful summary of temperature, rainfall, and duration of bright sunshine in the United Kingdom, for agricultural and sanitary purposes. This summary is arranged in twelve separate groupings for the various "forecast districts."

The inset map pages of this Report form a very valuable supplement to the D.W. Reports. For each day of the week ending 12 days before the day of issue of the W.W.R., there is given a chart showing morning observations over an area of some 280 degrees of longitude and 60 degrees of latitude, roughly centred on the British Isles. An inset map gives the evening conditions in Europe for each day, and a

weather summary adds to the value of each chart. The large area mapped, and the wealth of meteorological statistics given, render these maps of great value for tracing out pressure distributions and their related weather. A map on page 4 gives the actual sea surface temperatures for many of the two-degree squares of the North Atlantic and isotherms calculated for all readings received up to the time of going to press. In the case of all maps the sea is tinted; and for the Atlantic and the Mediterranean, normal sea surface temperature distributions are shown by means of different depths of blue tint.

Various appendices are issued from time to time, and contain tables showing comparisons with normal for certain weekly, monthly, quarterly and annual factors.

Monthly Weather Reports.

This is a twelve-paged periodical containing two pages devoted to monthly charts, and the whole is issued as a supplement to the W.W.R. Page 1 contains a complete analysis of the month with regard to the usual factors. The distribution of barometric pressure is fully dealt with, and the courses of important depressions are given. Outstanding or phenomenal weather conditions are described, and the most striking temperature maxima and minima are quoted. The distributions of rainfall and sunshine are analysed in percentages of the normal.

Page 2, Table I. gives district values for the month, and has descriptive notes on the statistical tables.

The next three pages of letterpress contain Table II., a mass of statistical returns from the Normal Climatological and Telegraphic stations. Important items are hygrometrical values and a summary analysis of the month's daily cloud and wind. Table III., occupying the next 4½ pages of letterpress, gives the returns from additional Climatological stations. The returns are less complete than those in Table A. The last page is partly occupied by Tables IV. and V., additional values of sunshine and summary of wind velocity for anemograph stations.

The maps on page 3 consist of four quarter-page lithographs of: (i.) Actual winds and mean pressure distribution, shown by isobars (normal values are given for comparison); (ii.) Movements of depressions; (iii.) Distribution of mean temperatures, shown by isotherms and scale of tints; (iv.) Bright sunshine (hours per day) shown by isohels and scale of tints.

Page 4 is occupied by a large scale map of the British Isles, with isohyets showing the monthly total rainfall in inches. This map is prepared at the Offices of the B.R.O. from data received from some 1000 stations; in addition to the isohyetal lines, blue tints of varying degrees of intensity assist in graphically representing the distribution.

The M.W.R. is issued on the 27th day of each month, price sixpence per copy. An annual summary is issued on similar lines to the above, and usually appears in February. The M.W.R. is particularly useful to teachers.

Marine Charts.

These large charts, 30 inches by 22 inches, are possibly the most valuable production of the Met. Office for many teaching requirements, yet are certainly less known than they deserve to be. Two forms of them are produced; the price in each case being sixpence per copy.

North Atlantic and Mediterranean.—The face of this is printed in five colours, and shows that section of the globe between 10° East longitude and 100° West longitude, and from the Equator to 60° North latitude. An enormous mass of data is shown, including such items as mean pressure distribution, fog, mist, ice, thermal zones of the North Atlantic, particulars of characteristic winds, ocean routes, and compass variations. The back of the chart has maps similar to those of the W.W.R., but less complete. Articles on topics of interest to navigators and others occasionally appear. [*Note:* Although the chart is referred to as the Monthly North Atlantic Chart, yet in reality it has been on issue *weekly* (Thursdays) since April, 1910.]

Indian Ocean Chart.—The main body of the chart contains information, much of it resembling that given for the Atlantic Ocean, and in addition, bold red lines indicate the isobars, while distinctive lines show the tracks of some cyclonic storms. The area, with a range of 95° of longitude and 65° of latitude, includes the Red Sea. The northern and southern limits of monsoons and trades are given, and during the south-west monsoon season important cable notices are included from the Director-General of Indian Observatories, with respect to the state of the weather conditions in the Arabian Sea and the Bay of Bengal. The back of the chart has a large scale map showing ice distribution in the Southern Hemisphere. The remaining space is utilised for articles on meteorological and oceanographical topics of general interest. This chart is issued monthly only.

Library and Museum.

The books and documents in the Office Library (Exhibition Road, South Kensington, S.W.), and the manuscript returns in the possession of the Office, may be consulted or copied at the Office free of charge by any person, by permission of the Director. The Museum of meteorological instruments, diagrams, etc., is open for inspection during office hours (10 a.m. to 4 p.m. week-days, excepting Saturday 1 p.m.). A permit may be obtained from the Director. Teachers and others visiting London are increasingly availing themselves of these facilities.

Publications of the British Rainfall Organisation.

"*British Rainfall.*" Temporarily edited by Mr. R. C. Mossman and the Assistant Director, Mr. C. Salter, during Dr. Mill's absence abroad. An annual volume, on issue usually in August. That of 1913, issued 1914 (about 500 pp.), contained :—

Part I. Two special articles relating to rainfall.

Part II. (*a*) Observers' notes on rainfall and meteorology of 1913; (*b*) The distribution of rainfall in time, analysed relative to heavy falls, droughts, monthly and seasonal amounts, relation of total fall to average, etc.

Part III. General table of rainfall at upwards of 5000 stations.

The book is fully illustrated, and all discussions are from the geographical standpoint. The maps in Part III., showing the various river basins of Britain, are of very great value to teachers.

Symons' Meteorological Magazine.

A small book issued on the 16th of each month, price fourpence. In contains many short articles of meteorological interest, written in a non-technical manner. It is specially valuable for its correspondence columns, and its rainfall table, which is the earliest tabulated statement published relative to any particular month.

Journal of the Royal Meteorological Society.

Issued quarterly (£1 per annum). It contains accounts of papers delivered in connection with the Royal Meteorological Society, correspondence, notices of books, etc., on meteorology. The publication is usually rather technical in character for the general reader. Up to the end of 1911, this Society supervised stations of its own, and published

the readings in a quarterly volume—"The Meteorological Record," 1/6. These volumes may occasionally be valuable for work requiring data in addition to those given in the M.W.Rs.

Other Sources of Information.

The Bibliography contains reference to other collections of statistics, etc., but attention should be drawn to the various newspaper charts of climatic facts. Pupils should be encouraged to cut out accounts of remarkable weather conditions, particularly when accompanied by illustrations, and they should make a point of collecting synoptic charts whenever possible. These may frequently be of value in illustration of essay work done away from the class-room.

SCHOOL CLIMATOLOGY.

Brief Discussion on Methods of Treatment.

General.

A school pupil will only study Climatology as an adjunct, though a valuable one, to the wider subject of general geography. The teacher himself may be sufficiently interested to research more deeply into the subject for its own great inherent value, but for the scholar it will only be possible to deal with the most general principles; though even to this degree, the training in accuracy through observation and tabulation, and the constant demand for the pupil to indulge in inductive reasoning, will yield valuable educational training.

Climatology must not be isolated from geography, in fact, it is inadvisable to use such awkward terminology as, e.g., meteorology, etc., and preferable to speak of the subject as "weather study." Many of the technical terms will intrude from time to time, and the danger in a subject of this nature is the mistaking of a glib use of a scientific terminology for a clear conception of related principles.

It is possible that a criticism will be levelled at the great stress laid on the use of local statistics and charts of the British Isles, and it may be argued that the actual area of the British Isles is so small that a study of the climatic factors of this particular region will only result in a knowledge of a very small portion of the climate of the globe. There is much in this objection, but the main object throughout is to teach pupils to read weather maps intelligently, and to approach the World's wind and weather through the study of the various weather maps and charts of the British Isles. It is accepted that a rational treatment of topography consists in an examination of the school locality, then a continued scrutiny of 25 inches, 6 inches, and 1 inch ordnance maps, so that the thoughts are carried in ever widening circles until the whole world has been included. A recognition of the various symbols on the O.S. map is an early exercise; this is suggested also for weather symbols. The contours, gradients, and streams on the one map, appear as isobars, gradients, and winds on the other chart; and with suitable reservations a parallel can be extended through many sections of the work, though it must be stressed early and often that for many maps the weather characters indicate rapidly changing conditions. The method throughout suggests comparisons with other areas and other factors, and in the case of the weather of the British

Isles it must be remembered that this is not a home-made product, but the result of far-reaching inter-relations which, individually studied, will take the pupil, in thought, over practically all areas of the globe.

Sections of the Subject.

Observational meteorology will be preceded by lessons dealing with the action of the various instruments and with experimental illustrations of their calibration. These lessons may be taken in connection with the course in Elementary Science or Experimental Physics; the actual construction of thermometers, thermoscopes, verniers, etc., has for long been a feature of these subjects.

The careful discussion of freezing point is necessary, as this temperature is a critical one relative to so many aspects of climate. Boiling point and its variation with pressure needs consideration, but still more important is evaporation, which in nature proceeds at all temperatures. This will introduce the wide question of humidity, absolute and relative. Experiments with the chemical hygrometer are valuable. Condensation in the abstract is exampled by clouds, fog, dew, mist, and rain in the concrete, while hoar frost, glazed frost, ice coatings, snow, and hail will have been discussed during the explanation of "freezing point."

Agricultural correlations will demand some explanations of "day degrees," "ground frost," and accumulated temperatures. Practical work with an experimental barometer will suggest the necessity for altitude corrections; and from this, the calculation of heights by means of the aneroid can be explained or preferably demonstrated. The calculation of altitudes by means of the hypsometer will follow, and the variation in the height of the "snow line" in various latitudes might be introduced here.

Convection currents need careful treatment, particularly in connection with planetary circulations. "Warming by compression" can be demonstrated easily, and will prove of value in the full discussion of such topics as "mountain and valley winds," föhn, chinook, etc.; rainshadow areas; helm clouds, etc. All these sections of the work belong rather to the Physics laboratory than to the Geography classroom, but failing systematic instruction in the former subject, they should be taken in the latter.

The utilisation of data, commencing with that of the station and extending to that from other sources, will demand help from the mathematical processes. Actual statistics should always be used, as simplified imaginary records contain many pitfalls which will sooner or later lead to disaster.

Example of Method.

Most of the following exercises are so worded as to suggest to the teacher the lines which the explanatory lesson should follow. It is advisable that each practical lesson should be broken into sections of explanation and experiment.

The pupils should clearly understand not only the exact requirements of any particular exercise, but also the reason for their spending time over this or that special problem. The following is given in illustration, and this actual treatment of a section of the work has proved to be successful.

Subject—Pressure Distributions: their related Winds and Weather.

Previous knowledge includes the meaning of the term "isobar" and a recognition of weather symbols.

I. A meteorological map of the world would be used to show different distributions of barometric pressure, i.e., "Highs" and "Lows." From month to month certain differences in position are indicated, but nevertheless certain high pressure areas and certain low pressure areas appear to be persistent.

Pupils trace this out, plot roughly the persistent areas and memorise their broad distributions.

II. D.W.Rs. would then be exhibited, to call attention to actual conditions as compared with average monthly or annual distributions. Attention is drawn to the indications of winds and their velocities and directions, as given on the chart.

The charts are then carefully examined by the pupils, who make a list of similarities of wind and weather in the various sections of the low pressure areas on the different charts.

III. The teacher then explains the need for compounding several of the charts; the pupils may suggest a method.

Tracing paper is issued, and the class work Exercise 50, and the words "cyclone" and "cyclonic winds" are introduced. At this stage it is possible to proceed and discuss two different aspects of future work:—

A. The position of the British Isles relative to the persistent "low" of the North Atlantic will lead to a discussion of the prevalent S.W. winds of the home area. Further extensions will take the class to the analysis of the "distribution of rainfall," "Gulf Stream drift," "winter gulf of warmth," etc.

B. Having prepared a similar compounded diagram, but containing weather conditions of the various areas in a "cyclone," the pupils, by examination of successive D.W.Rs., establish for themselves the fact that depressions travel. [The caution must be introduced here that

this is different from the travel of material objects, but rather resembles longitudinal transmission caused by transverse motion of the constituent particles—analogy, water wave transmission.]

It is recommended that the teacher takes a sheet of stout glass of suitable dimensions, and, by means of brush and various coloured inks, marks* on to the glass the various weather conditions characterising the different sections of a cyclone. If the sheet of glass be moved across a map of the British Isles, the class can deduce the sequence of weather associated with the passage of a cyclone over any area.

Pupils prepare simplified tracings showing similar facts, and are thus equipped for elementary practice in weather forecasting. D.W.Rs. will give the synoptic charts required, and the weather summary given on the following day can be used to check the scholars' attempts.

It will generally be found most satisfactory to work out one section to a legitimate conclusion; and though in this case it may be necessary to retrace some of the steps so that a second portion may be completed, yet the constant repetition of certain established truths will be valuable, and in many cases will prove a necessity.

Scheme of Exercises.

In the previous pages a suggestion has been made as to the extent to which pupils should investigate the various factors of climate. This is not intended to suggest a monotony of treatment, as the whole subject calls for elasticity; nor does the arrangement given imply that the exercises should be treated in that particular order. It is not intended that the following list shall be considered as exhausting the possibilities of the subject, but rather that it shall be used as a foundation for systematic practical work in climatology. Nevertheless it is believed that where facilities exist so that pupils can work through the full set of exercises, and where the scholars themselves will conscientiously endeavour to provide their own solutions, the result will be a sound working knowledge of the greater part of the subject.

There has been some little attempt at grading the work, but in general the arrangement is under various sub-headings, to facilitate reference to climatic factors.

Observational Climatology.

The instrumental equipment for this section is described on page 5. (*Note.*—The greatest care must be taken of station instruments. They must not be carelessly handled nor exposed to violent changes of temperature.)

* *Note.*—A thin coating of gelatine applied in solution to the surface of the glass will allow of the easy drawing of lines by pen or brush. The glass remains transparent, and the hint is particularly useful in the preparation of lantern-slide diagrams.

Thermometers.

1. Describe, with sketches, the forms of thermometers in use at the station.

2. Calibrate a thermometer tube for the lower fixed point.

3. Explain the action of the registering position of the maximum and minimum thermometers, and explain how they are "set."

4. For one month, read the dry bulb thermometer daily at 6 p.m. and at 2 p.m., in addition to the ordinary (9 a.m.) observations. Plot these observations on squared paper, together with daily maxima and also $\frac{1}{2}$ (maximum + minimum). What fact appears to be broadly established?

5. State the precautions necessary in the use of the "wet and dry bulb" thermometer.

6. At what period of the day is the relative humidity highest? and lowest?

7. Determine the "dew point" by means of an experiment with direct reading apparatus, e.g., Dines' or Daniell's Hygrometer.

Rain Gauge.

8. Describe, with sketches, the form of rain gauge in use.

9. Measure the diameter of the rim of the gauge, and compute by means of the formula $\pi r^2 h$ the cubic contents of 1 inch of rain in the gauge area. Test the rain gauge measuring glass by means of pipette, etc.

Barometer.

10. Describe, with sketches, the instrument in use. What arrangements exist for compensating for changes of cistern level? Why are they necessary?

11. Prepare a simple experimental barometer. Measure the length of the mercury column when the tube is vertical and when it is inclined to the vertical. What precautions does this suggest for the fixing and using of the station barometer?

12. Write an account of the movement of the mercury column under varying atmospheric pressures. What other form of hydrostatic balance might be used? (or) What is the principle involved in the action of the aneroid barometer?

Screen.

13. Why is a screen necessary? Why is it ventilated? Why is its opening towards the north?

Non-Instrumental Work.

Clouds.

14. Prepare chalk drawings of typical cloud forms.

15. Prepare a list of types of cloud forms arranged to represent varying heights, and indicate the kind of weather usually associated with each type.

16. Estimate velocity (slow, medium, rapid) and direction of cloud movements.

Winds.

17. State Beaufort's scale as estimated by the effects of varying wind velocities on certain objects. If possible, note and tabulate the effects of winds of varying velocities on the surface of a large piece of water.

18. Pick out the 16 compass directions for estimation of the wind direction when the wind vane is inoperative.

Weather.

19. Draw up a list of the recognised international weather symbols.

20. Make a collection of local and general weather sayings and predictions. Attempt to check their accuracy.

21. Examine and tabulate the sites of deposition of dew.

22. Examine crystals of hoar frost under a lens. Prepare sketches. If possible, quantitatively analyse the amount of hoar frost deposited on objects, grass, twigs, paper, iron, etc.

23. What depth of snow corresponds to 1 inch of rain? Sketch snow crystals. Notice position of any snow drifts in relation to natural objects and wind direction.

24. Register carefully the times of greatest intensity of thunderstorms. Make sketches of various lightning flashes. Trace any special deviations in the path of the storm. Estimate distances of storm from time to time (5 seconds interval between "flash" and "peal" = roughly 1 mile of distance).

NOTE.—The Meteorological Office appreciate early correct accounts of any important thunderstorms.

UTILISATION OF SCHOOL DATA (DIRECT USE).

Permanent registers should be kept containing all observations.

Temperatures.

25. Plot the daily mean temperatures on squared paper for one winter and one summer month. (For this purpose the half sum of the

daily maximum and minimum temperatures will represent the "mean" sufficiently accurately.)

26. Isolate the month's highest and lowest readings throughout the year, and graphically record them.

27. Calculate the "day-degrees" throughout January and July.

28. Calculate the "accumulated temperatures" during certain selected months.

29. Keep an account of first and last frosts in screen during the year. State the total number of nights with frost in screen during the year.

30. Make some observations on "screen minimum" minus "grass minimum." Relate differences to humidity and radiation.

31. Write a short account of "ground frosts"; their intensity, season and agricultural correlations.

Pressure and Winds.

32. Plot these two elements on squared paper together with temperature records for periods of sharply rising barometric pressure and sharply falling pressure. Search for correlations.

33. Plot monthly mean pressures, and monthly ranges of pressure throughout the year.

34. Construct "wind roses" showing monthly directions throughout the year. Correlate these diagrams with those of "rainfall."

Rainfall, etc.

35. Prepare graphs showing amount of rainfall daily for certain selected months.

36. Plot the following, month by month, throughout the year :—

$$\frac{\text{Total rainfall for month}}{\text{Number of rainy days per month}}$$

Is the expression "April showers" supported in the case taken?

37. With what type of storm is the heaviest rainfall associated (*a*) in winter, (*b*) in summer? In the case of the school acting as a collecting centre for district rainfall records, the following exercises might be taken :—

38. Plot the positions of all stations on an Ordnance Survey map. Prepare a tracing of the above map, adding contours. Endeavour to determine the factors (altitude, situation of prominent masses of high land, woodland, etc.), which appear to cause local differences in the total rainfall of the area.

39. Calculate percentages for several months as follows :—

$$\frac{\text{School station total rainfall} \times 100}{\text{Station B total rainfall.}}$$

$$\frac{\text{School station total rainfall} \times 100}{\text{Station C total rainfall}}$$ and so on.

To within what limits of accuracy are these percentages correct throughout the year?

40. What types of rains appear to cause distribution to diverge most erratically from the above ratios.

41. With what winds are (*a*) continuous rains, (*b*) short heavy showers, apparently associated?

42. Which type of rain tends most to cause local floods?

43. To what extent are local floods caused by rain in another area? Give measurements and details.

NOTE.—A short letter to the local newspaper asking for local details relating to floods will generally meet with a ready response.

Use of Tables.

44. Enter daily the 9 a.m. percentage humidity and vapour pressure in inches of mercury. (Calculated by means of tables used in connection with readings of the "dry and wet bulb" thermometer.)

45. Prepare tables for conversion of readings in degrees Centigrade into readings in degrees Fahrenheit, and *vice versa.*

46. Correct barometer readings daily for altitude, temperature, and latitude.

47. Convert inches of pressure into centibars; by calculation and by use of scale.

48. Convert inches of rain into millimetres of rain; by calculation and by use of scale.

49. Convert miles per hour into metres per second; prepare a graph for future conversions.

UTILISATION OF OTHER DATA FOR COMPARISON, ETC.

Comparisons of the records given for other "forecast districts" with the observations of the school station should be made frequently. Its position on the map relative to isohyets and isotherms should be constantly checked. Many comparisons will suggest themselves, and it is always advisable to mark the position of the station in red ink on the monthly maps (M.W.R.), and check the school observations against the various isograms given. (*N.B.*—Altitude affects temperature even as it does barometric pressure, though to a less extent.)

Temperatures.

50. On a suitable blank write the observations of temperature as given on page 1 of any D.W.R. Plot the isotherms. Compare with synoptic chart given on page 3.

51. Plot isotherms from observations marked on the maps of the W.W.R. Endeavour to indicate the position of the "pole of cold" in winter.

52. Copy January isotherms (M.W.R.) in black, and July isotherms in red, on a suitable blank map. Compare with the average lines as shown in a meteorological atlas. Analyse differences from average.

53. Select representative stations (M.W.R.) in the British Isles, and calculate range between January and July mean temperatures. Compare results with Exercise 52.

54. Prepare maps of the World's thermal zones, using mean annual isotherms (*a*) corrected for altitude, (*b*) uncorrected for altitude. Compare results.

55. Prepare maps showing areas where the average monthly temperature (i.) never exceeds 32°; (ii.) exceeds 50° for warmest month; (iii.) exceeds 68° throughout the year. If possible, two sets should be prepared as *a* and *b* in Exercise 54.

56. Suggest types of "natural region" which are roughly outlined on maps prepared in Exercise 55.

Pressure Systems and Winds.

57. Plot the isobars from the readings given on page 1 of any D.W.R. Compare result with the synoptic chart given on page 3.

58. Select D.W.R. charts with well-marked "lows." On a piece of tracing paper, mark a circle, 1 inch radius, with two diameters cutting at right angles; mark intersections on the circumference, N.S.E.W. Orient one of these tracings with the centre of the circle over the centre of a "low"; trace all wind arrows falling within the circle; repeat for several "lows" until the circle is reasonably well filled with arrows. From these establish the wind system of "cyclones." State Buys' Ballot's Law.

59. Prove the suitability of the term "cyclonic." Determine the directions of rotation.

60. Select a number of synoptic charts with well-marked cyclonic conditions, and trace the relations between closed isobars and isotherms.

61. Prepare similar tracings for both summer and winter seasons, but mark the commonly prevailing weather conditions in the four quadrants. Compare simplified copies of these tracings with published

diagrams of weather conditions in area under cyclonic pressure distribution.

62. Repeat Exercises 58 and 61, using well-marked "highs" or anticyclonic conditions. Contrast the tracings with the previous ones obtained for "lows."

63. Are the weather conditions prevailing in an anticyclonic area dependent on the season of the year? Analyse tracings and write out results in detail.

64. Examine relations between barometric gradients and wind velocities.

65. Determine the effect of the formation of a "secondary cyclone" on the wind direction and velocity in the primary. Note alterations of gradients.

66. Analyse wind directions and velocities in "ridge" and "wedge" type of isobar.

67. On a blank map, plot the path of movement of the centre of a well-developed cyclone, marking position of its centre as shown in D.W.Rs. at 7 a.m., 6 p.m., 7 a.m., etc., on consecutive days. Check by reference to map in corresponding M.W.R.

68. Combine the paths of movements of depressions as given in various M.W.Rs., and compare with annual summary.

69. By reference to M.C. 1 or to a meteorological atlas, determine and map the average position of the persistent low pressure area in the north of the North Atlantic.

70. From Exercise 58 and map prepared in Exercise 69, plot the direction of dependent winds, and from this establish the preponderance of S.W. winds for the British Isles.

71. What months show most regular S.W. winds? least regular? Why?

72. Refer to M.W.R. for data in support of conclusions from above exercise (71). Endeavour to account for any striking monthly exceptions.

73. Examine D.W.Rs., and select examples of northerly, south-westerly, and easterly types of weather in the British Isles. Sketch the arrangement of isobars for these types, and write an account of the associated weather.

74. Explain the system of the "trades" from an analysis of the distribution of the barometric pressure. Relate to thermal zones. Account for deflection to the right. State Ferrel's Law.

75. Trace out the alteration in the wind direction throughout the year in zone 0°—10° N. Lat. (M.C. 1). Account for this.

76. Trace out the alteration in the wind direction throughout the year in zone 0°—10° N. Lat. (M.C. 2).

77. What alterations in barometric pressure are shown in this zone, and in zone 0°—10° S. Lat.? Explain.

78. From M.C. 2, calculate the duration of the S.W. and N.E. "monsoons." Examine thermal zones in connection with these.

Moisture of the Atmosphere.—Precipitation.

79. Plot the areas subject to fog in the North Atlantic for each of the twelve months of the year. (M.C. 1.)

80. Analyse the distribution of fog and mist. Account for—

(*a*) Newfoundland fogs;
(*b*) Maximum polar fog belt in July;
(*c*) Mist belt west of North Africa;
(*d*) Irregularities in line marking southern distribution of fog.

81. Mark "highlands" on a blank map of the British Isles. Prepare a tracing showing average distribution of rainfall; superimpose the tracing and describe relations existing between distribution of heavy rainfall and physical features.

82. Examine M.W.Rs. for maps showing rainfall distribution presenting exceptions to principles discovered in Exercise 81. Trace out the effects of all well-marked long steady "cyclonic" rains or short sharp "thunder" rains on the total fall for the month.

If "British Rainfall" be obtained, (83) prepare an average rainfall map from the actual percentage map given. An area should be selected, and the exercise worked by means of the coloured map given and the appropriate statistics in Part III.

84. By planimetric or other calculations, determine the actual amount of rain in tons (roughly) for any particular "rain splash" illustrated in "B.R."

85. Analyse monthly maps of total rainfall ("B.R.") in relation to percentage maps for the same months, and trace out the effects of heavy falls for selected days.

86. On a large scale map of the British Isles, mark the climatic areas with special reference to isohyets and isotherms. Compare these areas with a vegetation map. Trace out connections between agricultural industries and climate—marking areas devoted to growth of cereals, to sheep runs, and to dairying pastures. (Physical features must be studied in connection with this exercise.)

87. On a map of the World, mark the climatic areas with reference to high medium and low temperature, and high and low rainfall. Compare with vegetation and industries map.

88. Plot isonephs from the statistics given in a series of M.W.Rs. Compare with isohels and isohyetal lines for the same months.

89. Combine maps showing precipitation, humidity, and cloudiness for selected months in the year. Endeavour to establish correlations.

Extra Work in relation to Marine Meteorology.

The information required for these exercises can be extracted from the charts of the North Atlantic (M.C. 1).

90. Plot the areas where the air over the sea is warmer than the sea itself. Where are these conditions reversed? Relate these results to those obtained in connection with Exercise 79.

91. Plot the areas showing greatest thermal change and those showing the least.

92. Trace the deviation of some selected sea surface isotherm, e.g., 50°, during the year. Analyse chief common sinuosities in isotherms. Establish correlations with prevalence of certain winds.

93. Relate the position of the mean path of centres of cyclonic areas to the movement of the high pressure zone during the year.

94. In which direction do the ocean currents normally set most regularly throughout the year? Choose several zones in connection with these exercises, and tabulate and plot the results.

95. In which zones do the ocean currents set most strongly? Where are they most variable?

96. By means of the information given on the back of the chart (sea surface temperatures), examine any striking alterations in the strength or direction of the ocean currents.

97. Plot the limits of drift ice and pack ice throughout the year.

98. Trace out the effect of the Labrador Current on the climate of Eastern North America.

99. Analyse the effect of the Gulf Stream and Gulf Stream Drift on the climate of N. Western Europe.

100. Plot the isanomalous lines from some meteorological atlas, determine the "winter gulf of warmth" for the Western North Atlantic, and relate results to Exercise 99.

101. Examine the ocean highways from season to sea in relation to the position of drifting ice. (This can be made of great value in connection with lessons on "great circle sailing," "Mercator's charts," etc., dealt with in Mathematical Geography and Cartography.)

102. Discuss the chief factors of a "Mediterranean" type of climate, using M.C. 1.

LITERATURE.

General.

The subject possesses an extensive literature, numerous books having been written for meteorological research, but generally their contents are highly technical in character. Many stress the physical side of the processes to such an extent as to detract from their value for the particular class of work under discussion.

The following Bibliography has been prepared in graded sections, so that teachers and others may be guided in their choice of suitable sources of information. Although many other valuable books may have been omitted through ignorance of their contents, yet those given are well-known standard publications of proved worth, and should be suitable in their turn for either preliminary reading or for advanced work.

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Junior:—Elementary study of climate with special reference to Britain. Prevalent winds, rainfall, and temperature.

Senior:—Leading facts about climate and rainfall, including the study of continuous records of climate observations. The study of the chief pressure and wind systems and other general influences as affecting the climate and characteristics of different parts of the World.

Higher Certificate:—More advanced work with maps of the World and its parts to show areas of various types of production, with a view to study of climatic and other factors at work.

WILLIAM JONES, Y DDRAIG GOCH PRESS, ABERYSTWYTH.

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